THE HERBACEOUS FLORA OF THREE WECHES FORMATION OUTCROPS IN EASTERN TEXAS

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ABSTRACT

The Weches Geologic Formation, which was formed during the Eocene Epoch, supports a herbaceous flora in a region where forest is the general climax vegetation. Soils are shallow and basic in contrast to the deeper acid soils of eastern Texas and the sites are usually waterlogged during spring. Species with the highest importance values in the Weches plant communities are *Sedum pulchellum, Satureja arkansana, Sporobolus vaginiflorus, Arenaria patula, Valerianella* spp. and *Trifolium dubium. Lesquerella pallida* and *Leavenworthia texana* are endemic to these outcrops. Disjunct species include *Calylophus drummondianus, Liatris mucronata, Paronychia virginica* and *Petalostemon pulcherrimum*. Species richness ranged from 49 to 81 species for the sites studied, while species diversity ranged from 3.23 to 4.56. Although the Weches sites contained many species in common with cedar glade plant communities in the southeastern United States, overall similarity was generally low.

RESUMEN

La formación geológica del Weches, formada durante la época Eocena, sostiene una flora herbacea en una región donde el bosque es el climax vegetal. Los terrenos son poco profundos y básicos en contraste con los terrenos más profundos y ácidos del Este de Tejas; los sitios por lo general están anegados durante la primavera. Las especies más valiosas e importantes en las comúnidades de plantas del Weches son *Sedum pulchellum, Satureja arkansana, Sporobolus vaginiflorus, Arenaria patula, Valerianella* spp. y *Trifolium dubium. Lesquerella pallida* y *Leavenworthia texana* son endémicas al Weches. Las especies dislocadas incluyen *Calylophus drummondianus, Liatris mucronata, Paronychia virginica* y *Petalostemon pulcherrimum*. La riqueza en especies varió de 49 a 81 especies en los sitios estudiados, mientras la diversidad de especies varió de 3.23 a 4.56. Aunque los sitios del Weches contienen muchas especies en común con la comúnidad de cedros en la región sudeste de los Estados Unidos, la semejanza en general no es muy grande.

INTRODUCTION

The geological deposits of eastern Texas are quite interesting because they result from activities of Gulf of Mexico waters and continental rivers (Sellards et al. 1932). Marine deposits were laid down when oceanic waters advanced over the land. When these waters receded, rivers deposited sediment seaward. Thus, there are several layers of marine deposits alternating with terrestrial deposits. The Weches Geologic Formation is a marine deposit formed during the Eocene Epoch. It extends from Sabine County near the Louisiana border to Atascosa and Frio counties in south central

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Texas in a line generally paralleling the coast. The formation is composed of glauconitic clays, marl and rich fossiliferous deposits. Mud stone often is associated with the Weches. Fresh exposures of the glauconitic stratum have an olive green cast, but they turn reddish-brown with age. These exposures usually occur naturally on the slopes of hills as a result of erosional activity. Generally, outcrops are about five to 20 m wide and occur in isolated or segmented strips, usually not more than 100 m in length.

Conditions associated with these outcrops are unique for East Texas. Because of the presence of mudstone, the soils are generally rocky and shallow, precluding the growth of woody vegetation. Hence, these sites are conducive to the growth of herbaceous heliophytes. In contrast, the predominant vegetation in East Texas is generally a pine-hardwood forest. Weches soils are basic and calcareous as a result of the rich marine fossil component (Sellards et al. 1932). Because of the glauconitic clay stratum, outcrops are often very wet, especially in early spring. Downward percolating water from overlying soils moves laterally over the impermeable clay of the Weches until it exits on hillsides where outcrops occur. On the other hand, soils frequently become very dry in summer and fall due mainly to their shallowness. These characteristics are in contrast to the generally acid, deep, well drained sandy loam soils of East Texas.

Interest in the floristics of Weches outcrops began in 1981 when E. S. Nixon and J. R. Ward rediscovered a population of a white flowered mustard, *Lesquerella pallida*, on an outcrop near San Augustine, Texas (Nixon et al. 1983). This species, which is endemic to outcrops of the Weches Formation, had not been seen since its initial collection in the 1830's. Since little was known concerning the plants that grow on the Weches Formation, we analyzed the herbaceous vegetation and compiled a list of plants of three naturally occurring outcrops.

STUDY SITES

The three study sites, located in San Augustine County in eastern Texas, are within Gould's (1975a) Pineywoods Vegetational Area and Braun's (1950) Oak-hickory Forest Region. The topography of the area is characterized by gently rolling hills. Average precipitation, which is fairly evenly distributed throughout the year, is about 122 cm and average annual minimum and maximum temperatures are about 12° to 25° C respectively (Larkin and Bomar 1983). January, February and March precipitation was below normal during the study year, 1986. This caused a reduced seepage flow over the Weches in early spring and thus affected the number of individual plants present. In contrast, May and June experienced above average rainfall.

The three study sites are located within pastures on gently sloping hills. Mudstone is exposed at all three sites. The Weches outcrops studied are about 60 m long and up to 20 m wide. Soils over mudstone generally are less than 15 cm deep, whereas those associated with the glauconitic clays are deeper. Some woody vines, shrubs and small trees occur on deeper soil but the sites are generally open. Some of the more common woody species are *Gleditsia triacanthos, Liquidambar styraciflua, Rosa bracteata, Juniperus virginiana, Forestiera ligustrina, Rhamnus lanceolata, Cornus drummondii* and the vine *Cissus incisa.*

The pastures have been mowed and grazed by cattle for many years. These factors undoubtedly have influenced the flora of the Weches outcrops. Topography and lack of woody plants generally hindered or did not require the mowing of the study sites. Pastures are usually mowed to impede woody plant invasion.

METHODS AND PROCEDURES

The herbaceous flora was analyzed using 50 x 100 cm quadrats. Two transects were established at each of the three study sites. The transects were parallel to the length of the Weches outcrops; and sample plots were placed every two meters along the transects. Thirty quadrats systematically were placed at each site in January of 1986. During the growing season (March through October) of 1986, quadrats were visited approximately every two weeks. During each visit, all plants were identified, and those in plots counted. Because *Valerianella radiata* and *Valerianella stenocarpa* can be distinguished in the field only by their small fruits (about 2 mm long), we lumped the two species. Based on collecting information, it is likely that *V. radiata* is the most abundant of the two species. For each species, frequency and density data were used to calculate relative frequency and relative density, which then were summed to give an importance value. Voucher specimens of all species on the three sites are on deposit in the Stephen F. Austin State University Herbarium (ASTC). Nomenclature follows Correll and Johnston (1970), Gould (1975b) and Kartesz and Kartesz (1980).

Sorenson's index (IS = 2C/A + B) was used to compare floristic similarity of the vegetation of the three Weches sites and of the Weches vegetation with the vegetation of cedar glades in the Southeastern United States. In this index, C is the number of species common to the two communities being compared, A is the total number of species in one community and B the total number of species in the other community.

Species diversity for the three Weches sites also was computed using the Shannon-Weiner diversity index (Shannon and Weaver 1949): $H^1 = - \Sigma pi$

$\log_2$ pi, where pi is the decimal fraction of the individuals belonging to the i^{th} species.

Soil samples were collected from the upper 15 cm of soil at the three study sites and pH, phosphorous, potassium, calcium, magnesium, and texture were determined by personnel at the Stephen F. Austin State University soil testing laboratory.

RESULTS

Soils

Soil pH at the three sites ranged from 7.6 to 8.2 and averaged almost 8. Levels of calcium (>2500 ppm), potassium (>250 ppm), and magnesium (>250 ppm) also were high. Available phosphorus ranged from 10 to 12 ppm. Soil textural class ranged from sandy loams to sandy clay loams.

Herbaceous Flora

Plants began flowering on the Weches outcrops during March, with the spring flora consisting primarily of *Satureja arkansana, Sedum pulchellum, Valerianella* spp., *Arenaria patula* and the introduced clover *Trifolium dubium* (Table 1). These taxa made up 62 percent of the density and 45 percent of the importance value of the spring flora. From March through May, 59 taxa flowered and 12,734 plants were recorded in the quadrats. These plants averaged 284 individuals per m^2.

The spring flora of the three Weches sites varied in species richness ranging from 45 taxa at site 1 to 35 taxa at site 3. Although site 3 had the fewest taxa, it had the highest number of plants (4,655), and thus the highest average number of plants per m^2 (314). *Valerianella* spp. and *Satureja arkansana* were the most important species at site 1; *Plantago virginica, Trifolium dubium* and *Melilotus indicus* were of secondary importance. *Trifolium dubium* was prevalent at site 2, along with *Arenaria patula, Plantago aristata, Bromus japonicus* and *Cerastium glomeratum*. *Sedum pulchellum, Satureja arkansana* and *Arenaria patula* dominated site 3. Fifty-three percent of the species on Weches outcrops flowered in the spring.

Species richness and density were lower in summer (June through August) than in spring. Species richness declined to 29 species and density to 23 plants per m^2 (Table 1). Only 1,021 plants were recorded in quadrats. During the summer, the Weches flora was composed primarily of *Croton monanthogynous* in association with *Euphorbia nutans, Cynodon dactylon, Helenium amarum* and *Euphorbia maculata* (Table 1).

Croton monanthogynous was important at all three sites. Other species with high importance values at site 1 were *Euphorbia nutans, Cynodon*

dactylon, Petalostemon pulcherrimum and *Palafoxia rosea*. At site 2, *Helenium amarum, Cynodon dactylon* and *Paspalum notatum* were dominants where as the more important species at site 3 were *Leucospora multifida, Euphorbia maculata* and *Croton capitatus*.

Grasses dominated the fall (September through November) flora of Weches outcrops, with *Sporobolus vaginiflorus* being the principal species (Table 1). *Lespedeza striata* was the only non-grass species among the top five dominants. These five dominants comprised 71 percent of the importance value and 73 percent of the density. Species present averaged 39 plants per m^2, nearly double the number present during summer (Table 1). There were 1,729 plants recorded in the 90 quadrats representing 24 species. *Sporobolus vaginiflorus* was the most important species at site 1. Associated species were *Digitaria ciliaris, D. ischaemum, Aristida oligantha* and *A. dichotoma*. These same species dominated sites 2 and 3 along with *Panicum hallii* at site 2 and *Lespedeza striata* at site 3. *Sporobolus vaginiflorus* had an importance value of 143 at site 3.

In summary, 112 herbaceous taxa were recorded in quadrats at the three study sites; site 1 had 81 taxa, site 2 76 and site 3 49. The 90 quadrats contained, at one time or another during the growing season, 15,484 plants. Dominants at the Weches sites included weedy introduced species such as *Trifolium dubium, Cynodon dactylon, D. ischaemum, Lespedeza striata, Bromus japonicus* and *Cerastium glomeratum*, the widespread rock outcrop plant *Sedum pulchellum*, plants that are indicative of wet sites like *Satureja arkansana*, and plants such as *Valerianella radiata, Sporobolus vaginiflorus* and *Croton monanthogynous* which grow on more mesic to dry sites. Most of the dominant taxa are rather small plants.

Forty-five herbaceous species were found on the Weches study sites in addition to the 112 recorded in quadrats (Table 2). Of these 157 taxa, 81 (52%) were annuals or biennials and 76 (48%) were perennials. These 157 taxa represent 39 plant families. The three largest families are the Poaceae (38 taxa), Asteraceae (16), and Fabaceae (14). These three families accounted for 43% of the Weches outcrop species. Of the species recorded in quadrats, 53% flower in the spring, 27% in summer and 20% flower in fall.

Indices of Similarity and Species Diversity

The index of similarity was 0.62 between sites 1 and 2, 0.63 between sites 2 and 3, and 0.52 between sites 1 and 3. Twenty eight taxa, most of which are weedy species, occurred at all three sites.

The species diversity index was 4.52 at site 1, 4.56 at site 2 and 3.23 at site 3.

TABLE 1. Frequency, density and importance value data for herbaceous species of three Weches outcrops during spring, summer, and fall.

Species	Frequency %	Relative Frequency %	Density No/M^2	Relative Density	Imp. Value[1]
Spring (March through May)					
Satureja arkansana	62.2	6.19	44.28	16.26	22.45
Sedum pulchellum	44.4	4.42	41.54	15.25	19.67
Trifolium dubium	73.3	7.30	31.38	11.52	18.82
Valerianella spp.	52.2	5.20	26.80	9.84	15.04
Arenaria patula	42.2	4.20	26.42	9.70	13.90
Others[2]		72.64	114.16	37.44	110.08
Totals		99.95	284.58	100.01	199.96
Summer (June through August)					
Croton monanthogynous	54.4	21.68	5.94	26.15	47.83
Euphorbia nutans	36.7	14.60	1.72	7.54	22.14
Cynodon dactylon	16.7	6.64	2.92	12.83	19.47
Helenium amarum	12.2	4.87	2.88	12.73	17.60
Euphorbia maculata	18.9	7.52	1.16	5.09	12.61
Others		44.66	8.08	35.69	80.35
Totals		99.97	22.70	100.03	200.00
Fall (September through November)					
Sporobolus vaginiflorus	75.6	22.74	14.92	38.81	61.55
Digitaria ciliaris	44.4	13.38	5.46	14.23	27.61
Digitaria ischaemum	41.1	12.37	4.24	11.05	23.42
Lespedeza striata	25.6	7.69	2.66	6.94	14.63
Aristida oligantha	26.7	8.03	2.34	6.07	14.10
Others[2]		35.75	9.84	22.92	58.67
Totals		99.96	39.46	100.02	199.98

[1]Sum of relative frequency and relative density.
[2]Other species recorded in plots at the study sites:

Acalypha virginica
Allium canadense
Ambrosia artemisiifolia
Andropogon virginicus
Anemone heterophylla
Arenaria drummondii
Aristida dichotoma
Aristida longespica
Asclepias verticillata
Astranthium integrifolium
Boerhaavia erecta
Bothriochloa saccharoides
Bouteloua curtipendula
Briza minor
Bromus japonicus
Calylophus drummondianus
Lesquerella pallida
Leucospora multifida
Liatris mucronata
Limnodea arkansana
Lolium perenne
Melilotus indicus
Mirabilis collina
Modiola caroliniana
Monarda citriodora
Nothoscordum bivalve
Oenothera speciosa
Oxalis dillenii
Palafoxia rosea
Panicum anceps
Panicum flexile
Panicum hallii

(Table 1 cont.)

Carex muhlenbergii
Cassia fasciculata
Cenchrus incertus
Cerastium glomeratum
Chaerophyllum tainturieri
Conyza canadensis
Croton capitatus
Croton glandulosus
Cuphea viscosissima
Cyperus flavescens
Cyperus ovularis
Dichanthelium laxiflorum
Diodia teres
Dracopis amplexicaulis
Eleocharis compressa
Eragrostis hirsuta
Eragrostis intermedia
Erigeron strigosus
Euphorbia dentata
Euphorbia spathulata
Galactia volubilis
Galium virgatum
Geranium carolinianum
Geranium dissectum
Hedeoma hispidum
Hedyotis crassifolia
Hedyotis nigricans
Heliotropium tenellum
Hordeum pusillum
Hypericum drummondii
Krigia occidentalis
Leavenworthia texana
Lepidium virginicum
Paronychia virginica
Paspalum dilatatum
Paspalum notatum
Paspalum setaceum
Petalostemon pulcherrimum
Phalaris caroliniana
Physalis viscosa
Plantago aristata
Plantago virginica
Poa annua
Polanisia dodecandra
Portulaca oleracea
Pyrrhopappus multicaulis
Ranunculus parviflorus
Sabatia campestris
Salvia lyrata
Setaria geniculata
Sherardia arvensis
Solanum carolinense
Sphenopholis obtusata
Sporobolus asper
Stachys crenata
Stipa leucotricha
Tridens flavus
Trifolium repens
Triodanis perfoliata
Trisetum interruptum
Verbena brasiliensis
Verbena halei
Veronica arvensis
Vicia angustifolia
Vulpia octoflora

Endemic, Disjunct and Rare Species

Only two of the 157 taxa on Weches sites in East Texas are endemic to Weches outcrops. One, the white flowered mustard, *Lesquerella pallida*, is listed as endangered by the U. S. Fish and Wildlife Service (U.S. Dept. of the Interior 1987). Only five populations of this species are known to exist, all in San Augustine County, Texas. With the designation of the Texas populations of *Leavenworthia aurea* as *L. texana* by Mahler (1987), this new taxon is now endemic to East Texas Weches outcrops. Although *Sedum pulchellum* is found only on Weches outcrops in eastern Texas, it grows on rock outcrops elsewhere in the southeastern United States (Clausen 1975).

Weches disjuncts include *Calylophus drummondianus*, *Liatris mucronata*, and *Paronychia virginica*, which are disjunct from the Edwards Plateau

(about 380 km to the southwest) and north central Texas (about 328 km to the northwest) (Correll and Johnston 1970). Another disjunct, *Petalostemum pulcherrimum*, is disjunct from central Texas about 225 km to the west (Correll and Johnston 1970). Other species considered rare in eastern Texas are *Heliotropium tenellum*, *Eleocharis compressa* and *Cuphea viscosissima* (Correll and Johnston 1970).

DISCUSSION

In contrast to the generally acid soils of eastern Texas bottomlands (pH 4.4 to 4.8, Nixon 1986), mesic uplands (pH 4.4 to 4.6, Nixon et al. 1980), and dry sandy uplands (pH 4.6 to 6.2,Ward 1984), Weches soils are basic with pH ranging from 7.1 (Nixon et al. 1983) to 8.2 (this study). Calcium content, likely a result of the fossilized shells of marine organisms, is much higher than that of the surrounding forest soils (Nixon et al. 1980, Marietta and Nixon 1983, Nixon et al. 1987).

In addition, Weches outcrops are partly characterized by shallow soils over mudstone. The shallow depth and dry conditions of summer generally preclude woody plant establishment. Some trees, shrubs and woody vines are present on the outcrops, but only in pockets or areas where deeper soils occur. Shallow soils also are characteristic of cedar glades in the southeastern United States, where they form over limestone and dolomite (Baskin et al. 1968, Baskin and Baskin 1988). Thus both the Weches and cedar glade communities, which are dominated by herbaceous species, are examples of edaphically controlled plant communities (Baskin and Baskin 1988).

Because Weches Formation outcrops in eastern Texas usually contain mudstone, communities growing on them can be classified as rock outcrop communities. These types of communities have received much attention in the southeastern United States (e.g. Baskin and Baskin 1985a, Baskin and Baskin 1988). Where limestone or dolomite is at or near the surface they are called cedar glades (Baskin and Baskin 1985a). Since eastern Texas is within the Eastern Deciduous Forest (Braun 1950), comparisons were made of Weches and cedar glade communities. Comparisons indicate some floristic similarity. All of the Weches dominants (Table 1), with the exception of *Trifolium dubium*, *Euphorbia nutans*, *Lespedeza striata*, *Digitaria ciliaris* and *D. ischaemum* are present in cedar glade communities (Baskin et al. 1968, Baskin and Baskin 1975a, Somers et al. 1986, Bridges and Orzell 1986). Quarterman (1986) noted that the thinner soils of Tennessee glades are dominated in the spring by *Leavenworthia* spp., *Arenaria patula* and *Sedum pulchellum*, and that *Sporobolus vaginiflorus* is a dominant grass on these soils during the summer.

Table 2. Herbaceous species recorded from outside the plots at the study sites.

Alophia drummondii	Ipomopsis rubra
Andropogon glomeratus	Lamium amplexicaule
Asclepias tuberosa	Lespedeza cuneata
Aster subulatus	Manfreda virginica
Aster texanus	Mecardonia acuminata
Berlandiera texana	Melica mutica
Cacalia plantaginea	Onosmodium occidentale
Cassia obtusifolia	Petalostemon multiflorum
Centrosema virginianum	Phlox pilosa
Chasmanthium sessiliflorum	Physalis heterophylla
Cyperus strigosus	Prunella vulgaris
Delphinium vimineum	Ranunculus fascicularis
Desmodium marilandicum	Ruellia humilis
Dichanthelium angustifolium	Ruellia pedunculata
Draba brachycarpa	Rumex pulcher
Draba cuneifolia	Sisyrinchium albidum
Elephantopus carolinianus	Sisyrinchium langloisii
Euphorbia bicolor	Sisyrinchium sagittiferum
Euphorbia corollata	Spiranthes cernua
Fimbristylis annua	Verbesina virginica
Galium pilosum	Viola pratincola
Gaura parviflora	Viola rafinesquii
Geum canadense	

Lists of species found on southeastern glades also were compared with our combined Weches list using Sorensen's index of similarity. Indices of similarity between cedar glade communities in middle Tennessee and the Weches were .26 (Bridges and Orzell 1986) and .25 (Baskin et al. 1968, Baskin and Baskin 1975a). Glades in Kentucky were less similar with indices of .17 (Baskin and Baskin 1975b) and .16 (Baskin and Baskin 1985b).

Plant families most representative of the herbaceous vegetation of Weches outcrops are the Poaceae, Asteraceae, Fabaceae and Euphorbiaceae. These same families are principal components of cedar glade communities in middle Tennessee (Somerset al. 1986). About one-half of the Weches outcrop species are perennials, whereas 70% percent of the 414 taxa of cedar glade communities in the southeastern United States are perennials (Baskin and Baskin 1985a). Fourteen percent of the 157 Weches site taxa are introduced whereas 20% of the cedar glade taxa are introduced (Baskin and Baskin 1985a).

Of over 400 taxa of vascular plants growing on cedar glades in the southeastern United States, 29 are endemic to those sites (Baskin and Baskin 1985). Only two of the 157 Weches taxa in eastern Texas are endemic

to Weches sites (Nixon et al. 1983). Baskin and Baskin (1985a) found that all of the endemic annuals were winter annuals and flowered in the spring. The two Weches endemics are annuals that flower in the spring. Baskin and Baskin (1988) noted that light, rather than soil or lack of genetic variability, seems to be the most important factor governing the distribution of annual glade endemics. Another interesting aspect is that narrow endemics such as those of glades seem to produce large seed banks to ensure their continuance (Baskin and Baskin 1978), which also seems to be the case with *Lesquerella pallida*. During a dry spring on a particular site less than 100 plants will occur as compared to 3000 to 4000 plants during a favorable wet spring.

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